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Application of the Image Processing Technique for Separating Sprouted Potatoes in the Sorting Line

Maryam Tavakoli, Mohsen Najafzadeh*

Young Researchers and Elite Club, Quchan Branch, Islamic Azad University, Quchan, Iran

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ABSTRACT

Grading agricultural and food products through manually sorting them is a very costly, difficult, and time-consuming stage in the quality control process. In addition, neither the performance of this method can be guaranteed nor is it possible to exert sustainable and uniform control on the food materials involved. Compared with traditional methods, computerized inspection of food products is more cost effective, sustainable, and efficient. Due to high customer demand for safe and high quality food products and due to the significant theoretical and practical developments in image-processing techniques in the past few decades, a system is introduced for separating sprouted potatoes in the sorting line based on the image-processing technique where the pictures taken by a digital camera are pre-processed in the Matlab 2013 environment. Subsequently, a new technique is introduced for identifying the sprouted areas in the potatoes.

KEYWORDS: Food safety, image processing, potato, morphologic, edge detection.

1- INTRODUCTION

Increasing customer demands to have access to high quality food materials produced in accordance with safety standards necessitates that quick, economical, non-destructive, and hygienic inspection methods be implemented to replace traditional quality control methods. Image-processing is one such technique used for providing exact descriptive data in agriculture and food industries, particularly for inspection and grading of fruits and vegetables, analyzing the characteristics of various cereals/grains, and evaluating food materials like meat, cheese, and pizza. In recent years, new image-processing techniques have been utilized for quality assessment of food materials. The theory of inspection and quality assessment of food materials via computer technology was investigated by Gunnasekaran (1996). Generally, image analysis and processing involves the following stages: taking pictures, converting these pictures into digital images, performing pre-processing operations for obtaining a modified image with the same dimensions as the original image, classification of images for the purpose of separating the digital image into disjointed spaces with no interfaces, and measuring the desired characteristics of food materials (size, shape, color, and texture), and classifying food materials into different groups.

Potato plant (Solanum Tuberosum) is a staple in the food diet of many people around the world and ranks second after rice in terms of widespread global distribution. Approximately 34% of the total potato crop is produced in Asian countries. Always being considered an important food product, potato was originally grown in the mountains of South America and was later discovered by the Spaniards. Potato is used in great amounts either in unprocessed or processed form (chips, French fries, and potato flakes). Probably due to its high calorie content, potato has, throughout the years, been a main supplier of energy in people's food. The protein in potato is of a high biological quality, supplying 8 or 9 types of amino-acids which cannot be produced by human body.

Due to the high consumption of potato and its being a staple in the diets of numerous people, precise control of this product is of particular significance. The most important factors to be considered in sorting potatoes in the production line of food processing plants are: separating unsound (broken, etc.) potatoes, separating stones and clods, and separating sprouted and green potatoes. Normally, sorting potatoes in practice mainly involves separation of unsound potatoes, stones and clods, and grading potatoes in terms of their physical characteristics (size and volume) without paying serious attention to separating sprouted and green potatoes.

Unlike wheat, lentil, and mung bean, vegetables like onion, garlic, and potato lose their nutritional value when they sprout, and eating the sprouted parts in these vegetables must be avoided. Potato sprouts produce increased levels of a toxic substance called solanine and eating the sprouts in large amounts can lead to poisoning. Solanine acts as the defensive system of potato, protecting it from various pests and diseases. Solanine exists in small quantities in and under potato peel. The allowable limit of solanine for safe consumption is 0.2 mg/g. However, when potato is exposed to light, green granules appear on its skin called chlorophyll. If this greening coincides with sprouting, then increased levels of solanine (up to 1 mg/g) can be produced, causing poisoning. Solanin is mainly concentrated inside the peel and at most to a depth of 3 mm under the same. Therefore, separating sprouted potatoes in the sorting line during production is highly important.

*1**Corresponding Author:** Mohsen Najafzadeh, M.S. Student, Computer Engineering, Artificial Intelligence, Islamic Azad University of Quchan, Young Researchers and Elite Club, Quchan, Iran. Mohsen.najafzaseh@iauq.ac.ir

For this reason, an attempt was made in the present article to design a system for separating sprouted potatoes from healthy potatoes in the sorting line. The purpose of this study is to make automatic potato sorting lines a reality, increase hygiene, and provide for rapid inspection of both raw and processed food materials.

2- Application of Image Processing in Food Industries:

Machine vision is the technology of preparing and analyzing computer images obtained from a real scene for the purpose of obtaining information or controlling a process. It is a non-destructive method for inspecting production lines in food processing industries. Today, image processing, a branch of computer science, is mostly used for processing digital images, and deals with processing digital signals representing the pictures taken with a digital camera or scanned by a scanner.

Image processing is divided into two main branches, namely, enhancing images and machine vision. Enhancing images includes such methods as using fading filters and increasing contrast for improving the visual quality of images and ensuring their correct display in the destination environment (e.g., printer or computer screen), whereas machine vision involves methods through which the meaning and content of images can be understood for such purposes as robotic applications and image orientation.

During the past few decades, image processing has improved significantly, both theoretically and practically. The progress in this field has been so fast that currently, image processing can be traced in many scientific and industrial applications. These applications are so dependent on image processing that they are basically useless without it. According to experts, manual quality control methods have the following disadvantages:

- Low accuracy due to such factors as poor lighting, personnel fatigue, etc.,
- Lack of consistency due to earlier factors,
- Lack of integrity as a result of earlier problems.

Using artificial (machine) vision in the grading process not only reduces the identification time, but also coordinates the grading operation as well. This leads to more uniform quality assessments. In recent years, numerous studies have been conducted on using machine vision techniques for quality assessment of agricultural products. Wolf et al. conducted a study based on the shape of green pepper. Morph et al. developed a technique for quality control of potatoes based on potato size, color, and shape. Stevenson and Chamberlain developed color standards for grading tomatoes based on reflection of light. Tau set al. analyzed color images for classification of potatoes, dividing them into 6 groups. Castel et al. used neural networks and fuzzy logic for grading tomatoes.

Image edges are those pixels in an image where a large difference exists between neighboring pixel intensities. Image edges are obtained by taking the derivatives of the image function in the x and y directions, and then calculating the gradient at each point of the image. Image edges comprise those pixels in the image the gradients of which are greater than a threshold value.

Various upper-pass filters have been designed for calculating the first-order derivative of the image. Of these, the Prewitt, Sobel, and Frei-Chen filters are more important. Each of these filters consists of two different masks which accordingly calculate the derivatives of each image point in the x and y directions. Note that the derivative mask in the x direction is the transposed of that in the y direction and vice versa.

3- METHODS AND MATERIALS

The machine vision system consists of a software section and a hardware section. The former comprises the computer, the camera, and the lighting units, and the software section uses Matlab to process images. The reason for selecting Matlab was its high power in analyzing color images and its powerful image-processing functions.

4- Image acquisition:

The Image acquisition system first takes pictures in different directions with a digital camera. To provide suitable lighting, the potatoes are placed on a white plate before taking the pictures with the digital camera. Then, the obtained pictures are pre-processed to reduce their noise and improve their contrast. In the proposed method, first the required pictures were taken with a digital camera. Subsequently, the noise elimination and contrast improvement operations were conducted on the images. The degree of redness or greenness of the sprouts are shown in the images obtained via morphologic functions (Figure 1)

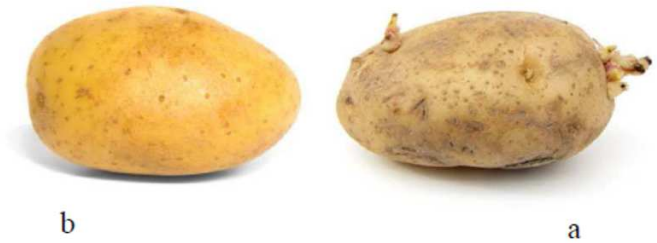

Figure 1- Potato Samples: (a) sample with tuber sprouts, (b) healthy sample

5- Image Processing Procedure:

The algorithm procedure used in the program is as follows: First, to reduce image volume and increase image processing speed, the image was converted into gray surfaces. Then, the Prewitt filter was applied. The Prewitt algorithm is very similar to the Sobel algorithm, with the only difference between the two beings in their mask coefficients. The Prewitt algorithm applies onto the image a vertical and a horizontal mask with known coefficients.

p1 p2 p3	1 1 1	-1 0 1
p4 p5 p6	0 0 0	-1 0 1
p7 p8 p9	-1 -1 -1	-1 0 1
A 3x3 Sample Window	Horizontal Filter	Vertical Filter

The formula used for calculating pixel p5 is one of the two following cases:

$$Pixel = (p1+p2+p3-p7-p8-p9) + (p3+p6+p9-p1-p4-p7)$$

Or:

$$Pixel = SQRT((X*X)+(Y*Y)) \text{ [where } X = (p1+p2+p3-p7-p8-p9) \text{ and } Y = (p3+p6+p9-p1-p4-p7)]$$

Using the Imdilate function, we expanded the edges found in the previous stage based on a diamond-shaped structure to a radius of 2. Subsequently, the Imfill function was used to change to white the color of the holes (black spots) found in the image. Then, two linear structures (one horizontal at 0 angles and the other vertical with an angle of 90 degrees) as well as the Imopen command were used to eliminate the extra objects in the image. Ultimately, a number of holes remained, which revealed the locations of the sprouts. Thus, it was possible to check if any sprouts could be found on individual potatoes.

This algorithm was applied in the following case studies: two potato samples (Figure 1), one potato with several sprouts (Figure2), and one healthy potato (Figure 3). The finding and highlighting of the sprouts are exhibited in Figure 2 where the number of the areas can be adjusted via the bwboundaries command. As can be seen in Figure 3, no such as are observed, thus, the proposed system would declare the scanned potato as “sound”.

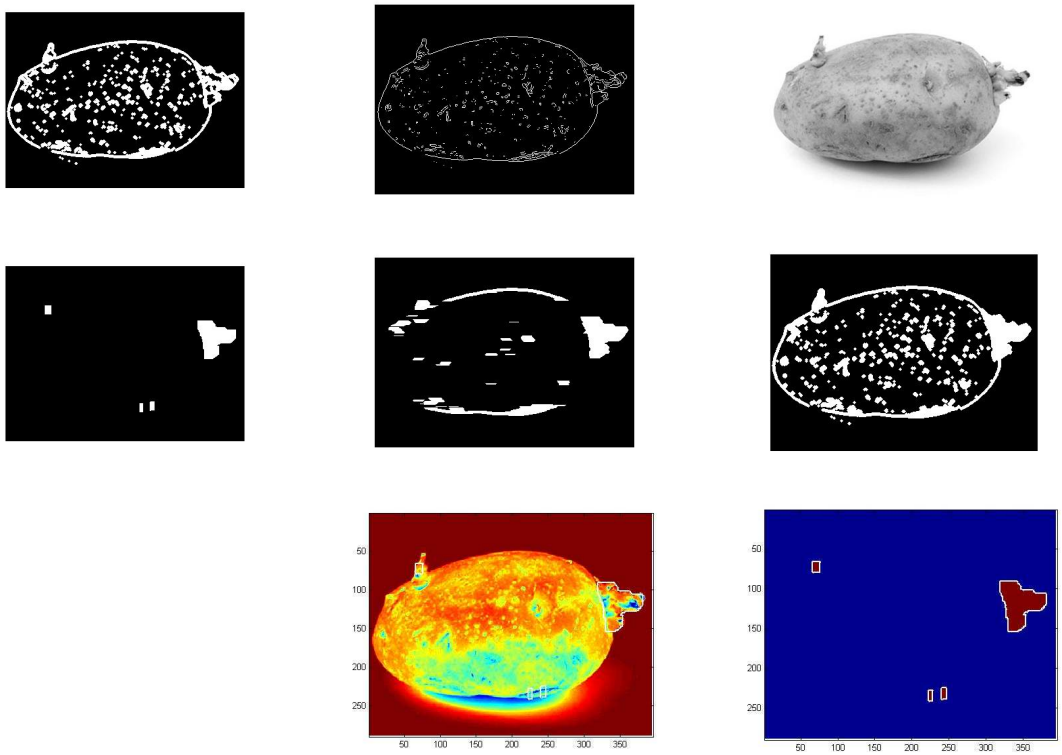

Figure 2- Running the program for a sprouted potato and detecting several sprouted areas

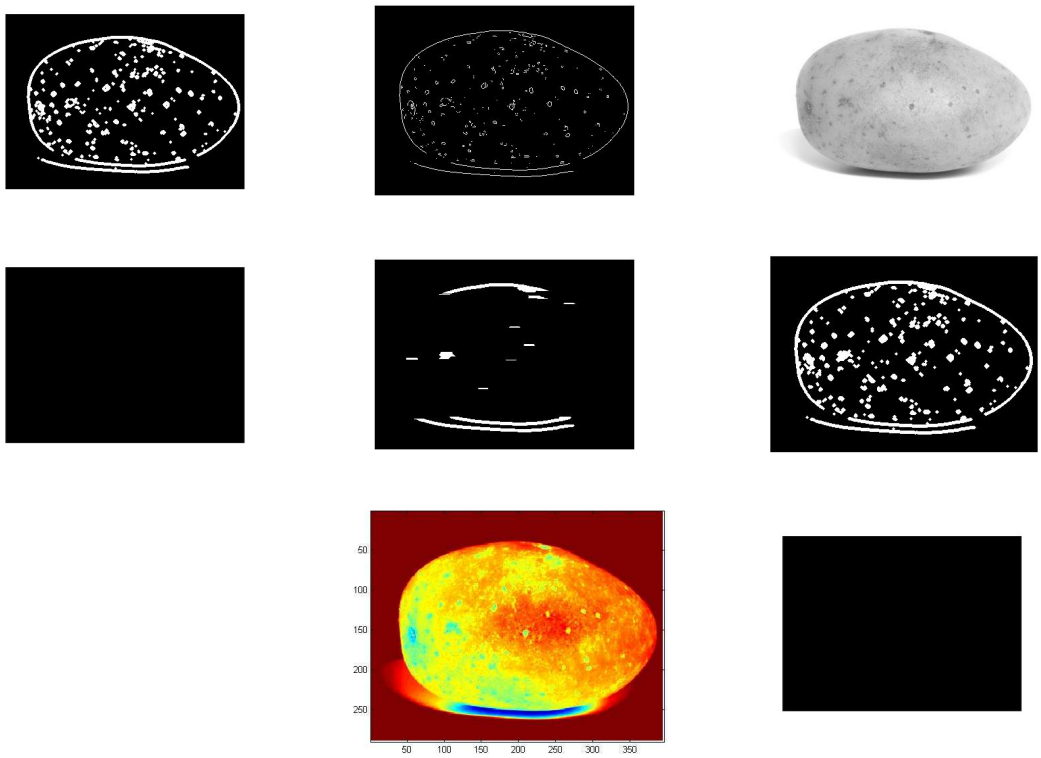

Figure 3- Running the program for a healthy potato: No sprouts are observed

6- Conclusion:

The obtained results showed machine vision was an efficient system for determining qualitative characteristics of agricultural products like potato. Using smart digital cameras and image-processing software, machine vision can perform separating operations. Also, machine vision is a non-destructive and non-aggressive method for controlling the quality of food products. Development of software and hardware technology has made available low-cost solutions which have spread the use of machine vision systems for quality inspection of food materials. By introducing small changes, this method can be applied for other products as well. The proposed program was meant for separating sprouted potatoes form healthy potatoes with high accuracy, and can be a useful step in increased safety for customers. Placing a mechanical arm at some point along the production line can lead to complete sort-out of the undesirable products. Implementation of this system in potato sorting lines can raise awareness regarding the efficiency of the system. Also, economic calculations conducted before such implementation would be indicative of the relative advantage of the proposed method as compared with other methods.

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